1908

A MODERN STEAM POWER CENTRAL STATION

DESIGNED AND INSTALLED BY

CHAS. C. MOORE & CO. ENGINEERS

SAN FRANCISCO, CAL.

A Modern Steam Power Central Station

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MAIN OFFICE, SAN FRANCISCO, CALIFORNIA

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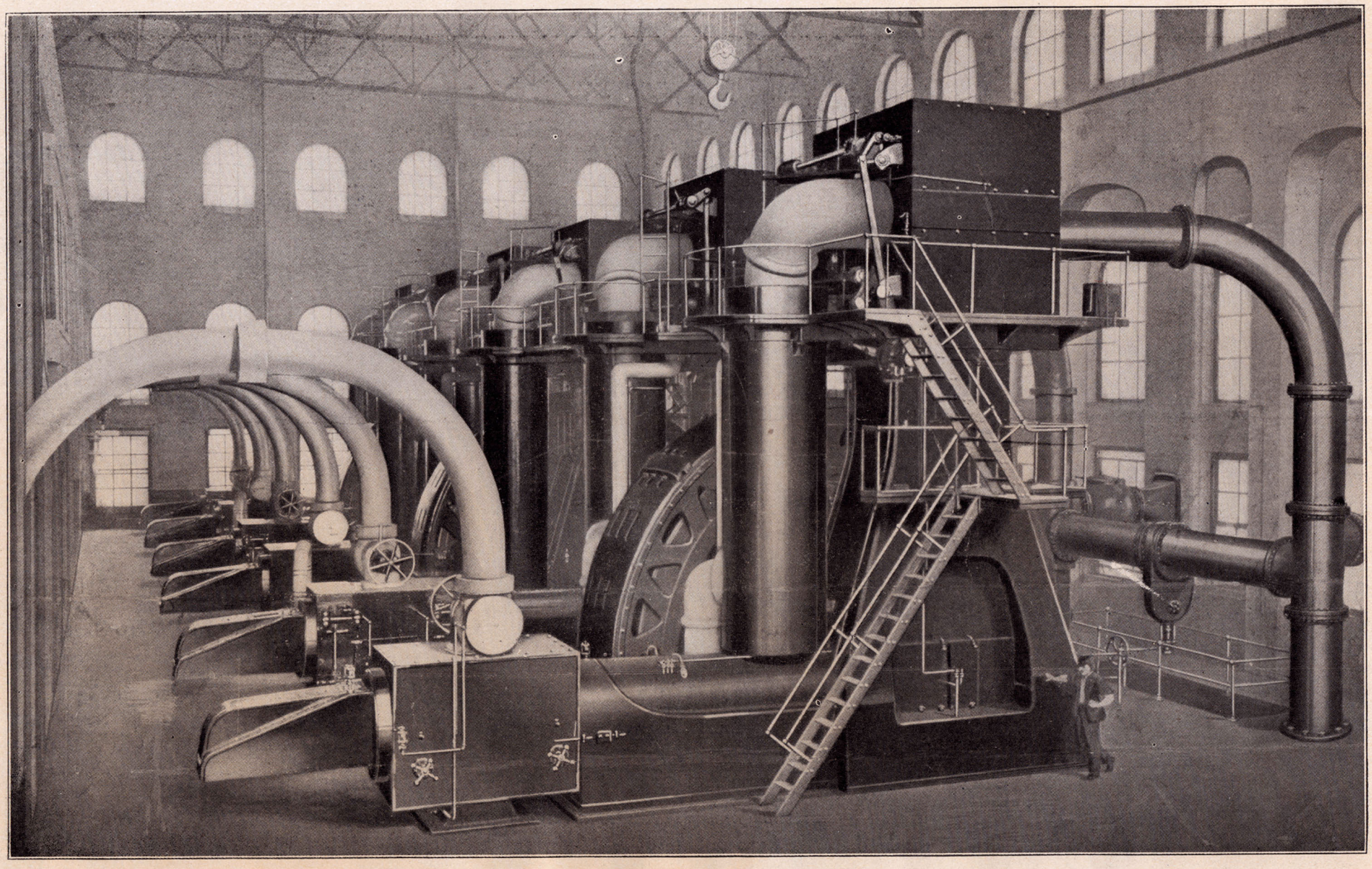


View of Engine Room from Northwest Corner

A Modern Steam Power Central Station

ONE of the most striking examples of recent steam power plant design is the plant of the Pacific Light & Power Co., operating at Redondo, California. The most radical departure from recent Eastern central station practice lies in the adoption, as prime movers, of one of the most modern types of reciprocating engines in lieu of steam turbines.

Considerably at variance with the customary method of procedure with large plants, the Purchasers, desiring to secure the most modern and economical steam power plant possible, entrusted the design of this station to a firm of Contracting Engineers with whom was placed a fixed sum contract for the entire installation.

As customary guarantees for water consumption of prime movers, efficiencies of boilers and various auxiliaries, under ideal conditions, were considered of no protection under commercial conditions of variable load, a definite complete plant economy was guaranteed, based on commercial railway load, subject to penalty and bonus stipulations.

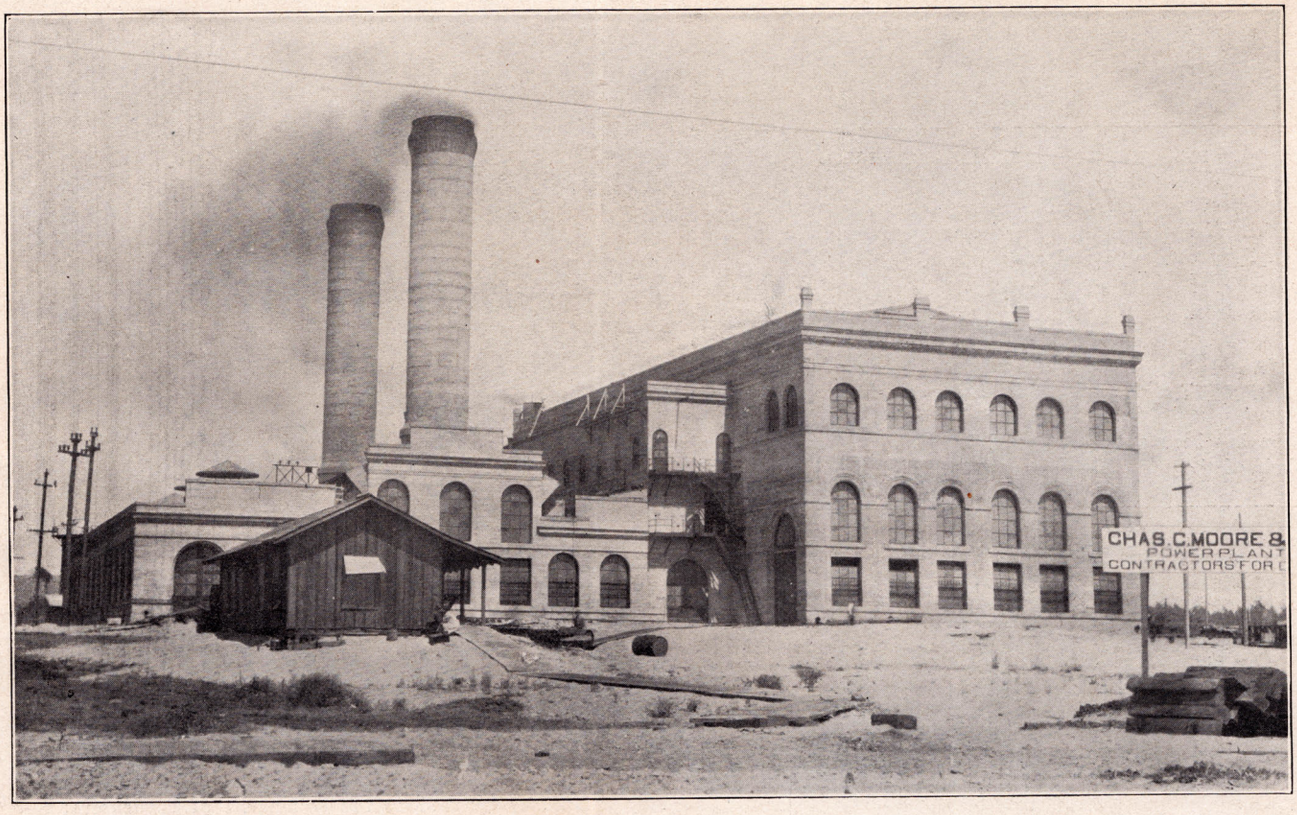
A further feature of interest was the provision of the contract that the plant be started and operated by the contractor for a period of at least three months previous to the economy test, also during test, thus thoroughly organizing the operating crew and perfecting the adjustment of the apparatus.

The test to determine the economy of the plant was to have been of ninety days duration on one unit operating on commercial railway load. Inasmuch as the plant had been operating regularly over six months previous to test, it was considered that the endurance run was an unnecessary feature of test, and the test period was therefore reduced from ninety to fifteen days.

As a result of undoubtedly the most elaborate power plant test ever undertaken, the Committee in charge have reported an actual economy under commercial load, which has not only earned for the contractors the largest amount of money ever paid as a bonus on a steam power plant guarantee, but has also exceeded the economy of any central station of published record.

The contract for this station was placed with Chas. C. Moore & Co. Engineers, of San Francisco, California, the plant having a nominal capacity of 15,000 K.W., there being three units of 5,000 K.W. each; the contract covered the entire plant installation, including machinery foundations excepting only switchboard, building, circulating water pipe line, wharf and any other work outside of the building.

In order to obtain an ample supply of water for condensing purposes, the plant was located at Redondo, a beach town eighteen miles southwest of Los Angeles.



View of Building from the West

Eighteen thousand volts were determined as ample for this distance of transmission, the alternators being wound for this potential without the use of step-up transformers.

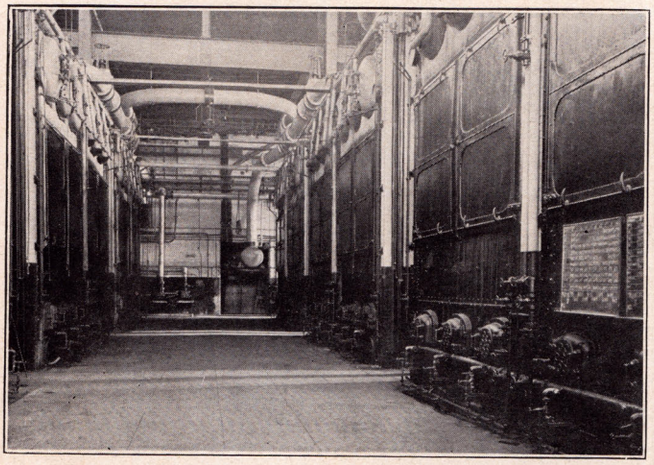
The Pacific Light & Power Company is engaged in both lighting and power business, although the greater part of the current from this station is used for operating the railways of Los Angeles and suburban towns, including all of the well known Huntington system of inter-urban railroads.

An interesting feature of this station is its successful parallel operation with other water and steam power plants, belonging to the extensive holdings of the Pacific Light & Power Co.

The fuel situation is ideal. Crude oil is obtained from wells near the plant, in which the power company is largely in-

terested. Owing to the system of oil firing in use, the boiler room labor cost is at a minimum. Consideration of these facts in connection with the remarkable economy attained warrants the statement that this plant is developing steam power at a cost probably lower than that of any other large American Central Station.

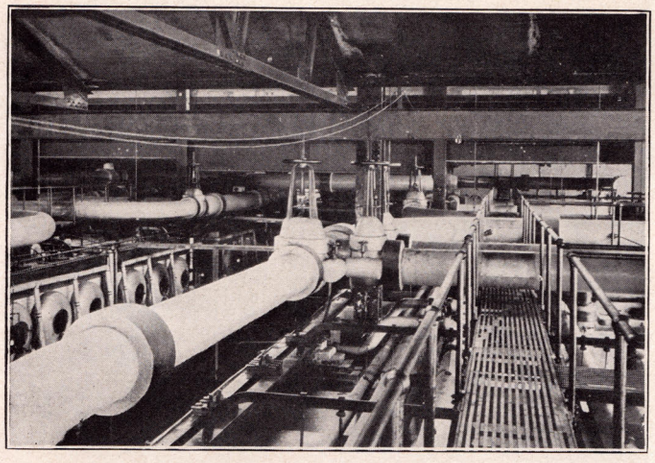
While this station is a record breaker for economy, the designers maintain that had fuel cost been of greater consideration, even greater efficiency could have been attained, as a number of minor points of economy were sacrificed in favor of simplicity of design and operation.



Firing Alley Between Second and Third Units

The panel system of design was followed, as will be noted from the accompanying drawings. Owing to the fact that each main engine consists in reality of two compound engines connected to the one shaft, each having an independent steam and exhaust connection, a further subdivision has been possible with each unit in the connection of one-half of the panel of boilers to each high pressure cylinder,

GENERAL ARRANGEMENT.



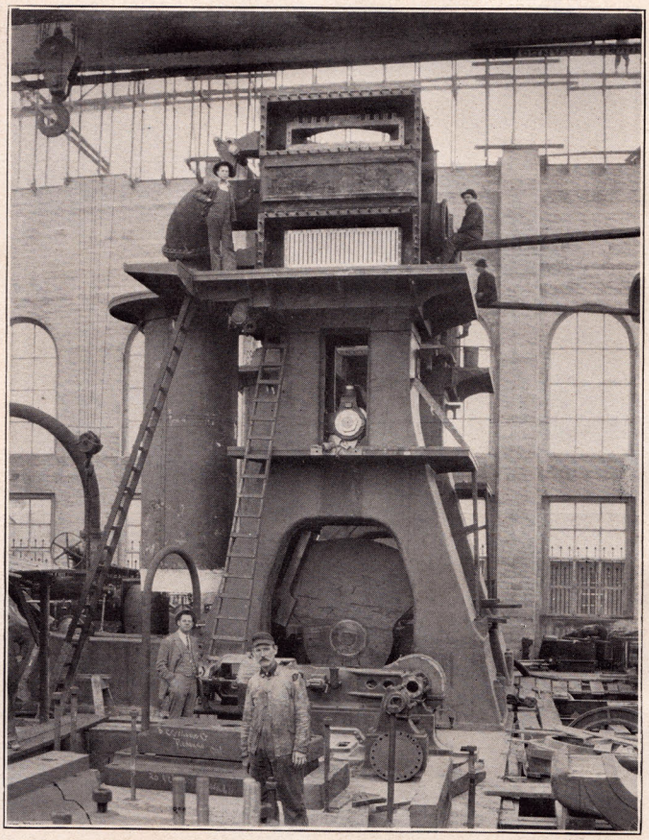
Pipe Platforms on Tops of Boilers

and the provision of a separate condenser and air pump for each low pressure cylinder, giving in effect the freedom from breakdown corresponding to six instead of three plant units.

All auxiliaries, excepting air pumps, are steam driven, operating non-condensing, the exhaust steam being utilized in feed water heaters.

The air pumps for each unit are motor driven, power being furnished from the main generator, insuring gradual starting of both air pumps in synchronism with main engine.

The adoption of a syphon system of suction and discharge pipes for circulating water, is due to location of plant, the use of conduit or canal system being impossible. There are two 50″ suction mains and one discharge line of same size and these are supported on a pile wharf carried out to deep water at low tide. The suction pipes are primed by means of a large motor driven vacuum pump operating through a stand pipe, which prevents carrying of water into vacuum pump cylinders. When once started suction is maintained by three engine driven centrifugal circulating pumps, located in pump pit, there being one pump for each unit. Each pump has separate connections to both suction lines. All pumps discharge into a common supply main having inlet connections to all condensers. All condenser outlets are connected to the one return main. The



McIntosh & Seymour Engine in Course of Erection Showing Vertical Low Pressure Cylinder

flexibility of this system of condensers is at once apparent. Any pump may be used to supply any set of condensers; although when two or more pumps are running their operation is necessarily in parallel. The regulation of relative amounts of water through various condensers is accomplished by the condenser discharge valves; the pumps are speeded up or down, and the number of pumps in service is increased or decreased as load conditions require.

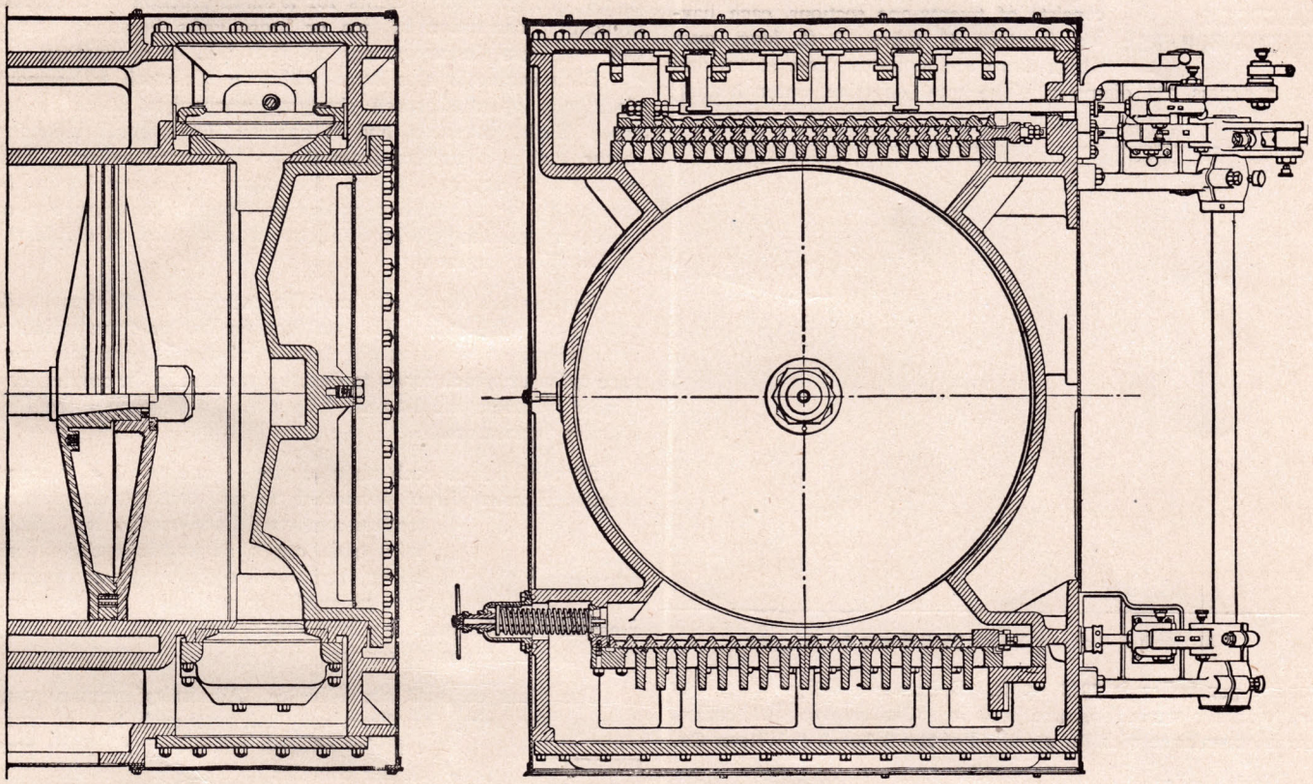
The provision of two condensers on each unit, with cross connected exhaust, is a marked feature of this installation. Should it become necessary for one condenser to be cut out of service, the exhaust steam from both low pressure cylinders may be led to the remaining condenser, making operation non-condensing unnecessary, except for a failure of circulating water or the breakdown of both condensers at one time. Actual operation shows but slight falling off in vacuum due to this doubling of load on one condenser. Eliminating air leaks in exhaust pipes and minimizing the loss of vacuum due

to pipe turns has been given very careful consideration in all its details, the vacuum joints being as carefully made as in high pressure steam piping. In regular operation with ample water at 70 deg. F., vacuum from 28″ to 28.5″ is easily maintained.

Each condenser is provided with an Edwards triplex suction valveless air pump, motor driven.

on nominal load, the sixth being for reserve. The waste gases from boilers discharge through short re-inforced concrete flues to centrally situated re-inforced concrete chimneys.

A novel feature of the boiler plant is the use of secondary tight fitting sliding dampers, which are completely closed during standby period, to cut down fuel loss due to circulation of



Sections of Vertical Low Pressure Cylinder

Each air pump discharges into a vertical stand pipe to eliminate entrained air, after which the water, subsequently used as boiler feed, is passed through a Volz heater, being in effect a primary heater in the upper portion of condenser shell. The feed water is thus heated by the exhaust steam entering condenser materially increasing the plant economy.

The feed is next passed through a Marine type feed water filter, in order to remove any excessive quantity of cylinder oil, after which it enters the suction main and is pumped into boilers, passing through auxiliary heaters enroute. The successful treatment of feed water containing quantities of cylinder oil seems to have been successfully accomplished only on the Pacific Coast. In this station or in others the complete separation is not attempted, but the plant is regularly operating, reasonable care being exercised in feeding oil to main engines, with such degree of separation as to place the plant on a practicable operating basis. Entrained oil in exhaust from auxiliaries is so completely removed by means of Cochrane Exhaust Oil Separators that this condensed steam, drained from the body of closed Goubert heaters, is as clear as drinking water, and is used for feed purposes.

All boilers are fitted with superheaters, designed for approximately 100 deg. F. superheat at boiler nozzles, giving from 80 deg. to 90 deg. at main engine throttles. Working steam pressure is 175 lbs. maintained at engine throttle. All auxiliary engines operate on same steam pressure and superheat as main engines with no difficulties due to valves, wear, etc.

There are six Babcock & Wilcox Boilers in each panel corresponding to each main engine, five boilers being operated

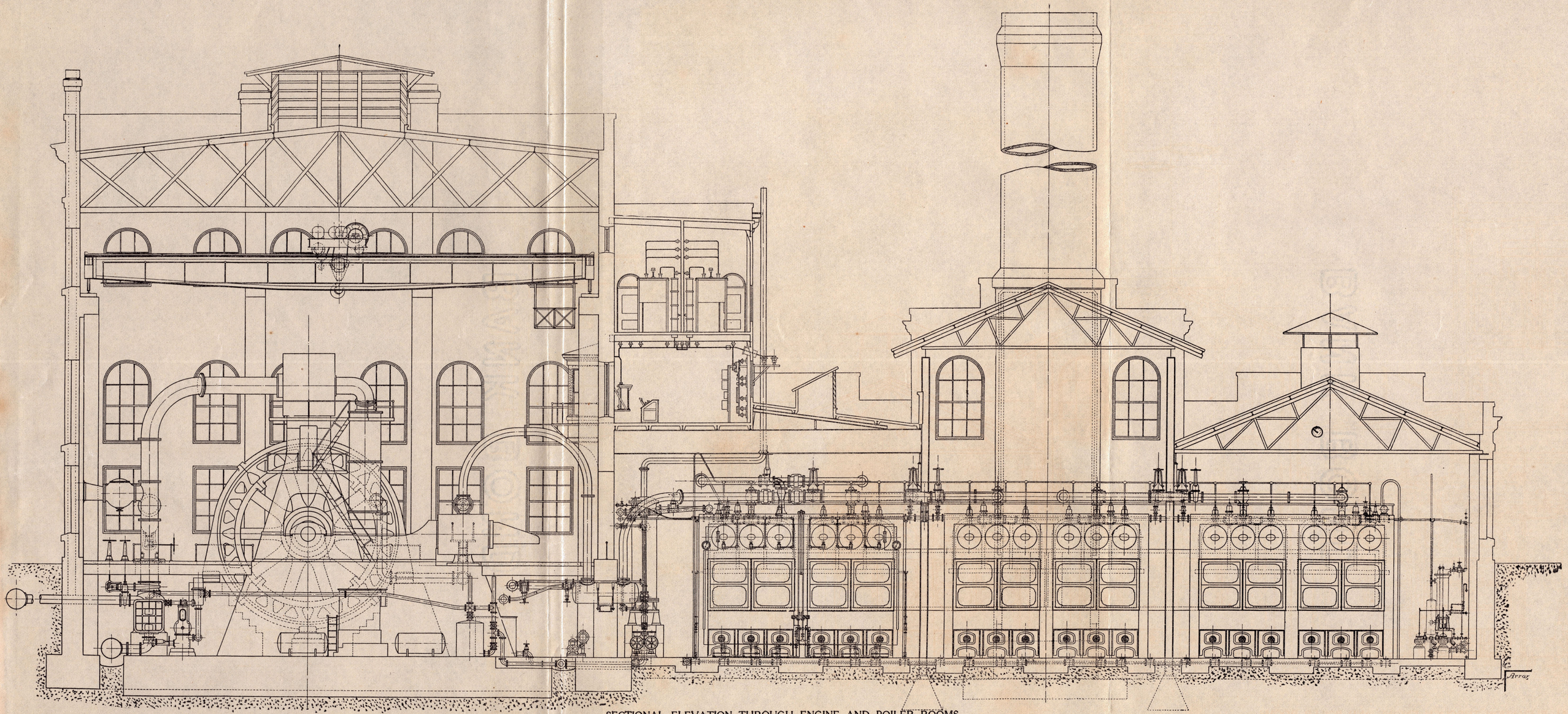
cold air through boiler setting.

Boilers are fitted with Peabody Oil Furnaces, burners firing forward from bridgewall as shown on drawing. Fuel oil is supplied to burners by steam driven pumps. The system of storage and handling of fuel oil being more fully described below. For each panel there is one large Snow Feed Pump, having compound steam end; a fourth pump answers as reserve for the entire plant.

As is common with all McIntosh & Seymour engines, a superheating receiver is placed between each set of high and low pressure cylinders, superheated steam being supplied to the heating coils at boiler pressure. The condensation from these coils is almost as hot as the water within the boilers, and the proper disposition of this hot water materially affects the economy of the plant. Each unit is provided with one Snow receiver pump, enabling the return of this hot feed direct to boilers. Each McIntosh & Seymour engine is controlled by a shaft governor, operating the auxiliary cut-off valves, on admission to both high pressure and low pressure cylinders. Large counter-balances are provided on engine shafts, insuring smooth running under all conditions.

Previous to acceptance of plant, an actual demonstration was made, showing that unit could be successfully run with one, two, three or four cylinders; also with one end of any cylinder out of commission. As one cylinder of the unit is at worst liable to injury at one time, the period of shutdown is at most practically limited to that necessary to disconnect one rod.

The plant is complete with minor auxiliaries for convenience in handling and filtering oil, circulating and cooling



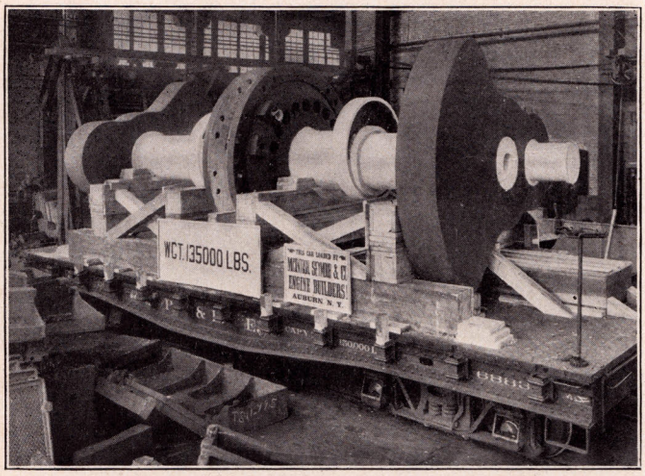
SECTIONAL ELEVATION THROUGH ENGINE AND BOILER ROOMS

water for main engine guides and bearings, facilities for boiler cleaning, feed water purifying and also salt water fire protection.

The main apparatus in detail is described as follows:

BABCOCK & WILCOX BOILERS:

There are eighteen Babcock & Wilcox Patent Safety Water Tube Boilers of Forged Steel Construction, arranged in nine batteries of two each. Each boiler consists of twenty-one sections, each having fourteen 4" tubes 18 ft. long, over which there are mounted three steam and water drums 42" diameter. The total effective water heating surface per boiler is 6042 sq. ft. Boilers are designed for 200 lbs. working steam pressure, and in other respects the boilers are in accordance with the standard of the Babcock & Wilcox Co.



McIntosh & Seymour Engine Shaft Ready for Shipping

SUPERHEATERS:

Each boiler is equipped with one Babcock & Wilcox forged steel superheater, designed to give approximately 100 deg. F. superheat at the boiler nozzle. This superheat can be slightly increased or decreased at will by the arrangement of baffling over the first pass.

FURNACES:

Each boiler is provided with a Peabody Patent Fuel Oil Burning Furnace. This furnace affords the most efficient boiler performance with crude oil. The furnace is fired from the bridge wall forward, but is controlled at the boiler front. It offers a large volume diverging in the direction of the flame. A large surface of brickwork is exposed, insuring complete combustion. The distribution of flame is over a large area of boiler heating surface, preventing localization of heat and blow-pipe action, and minimizing the possibility of burning out tubes. The furnaces are arranged for the use of three burners per boiler.

McINTOSH & SEYMOUR ENGINES:

The plant includes three 34x70x56 combined double horizontal and vertical, compound, side crank, McIntosh & Seymour automatic grid-iron valve engines, each directly connected to one General Electric 5000 K. W., 50 cycle fly-wheel-type alternator, speed 100 r. p. m. Each engine has two horizontal high pressure cylinders and two vertical low pressure cylinders, designed to operate with 175 maintained throttle pressure, 100 deg. F. superheat. The engine governor, which is of the well known McIntosh & Seymour type, is designed to go into the fly-wheel generator.

The valve gear is also of the well known McIntosh & Seymour type, having grid-iron valves. The admission and exhaust valves for all cylinders are operated by means of fixed eccentrics. The point of cut-off in each cylinder is controlled by an auxiliary valve actuated by the one engine governor.

Each engine is fitted with McIntosh & Seymour patented compound delaying dash-pots for parallel operation. They control the governor weights for a small fraction of a second, preventing oscillation of two or more units becoming amplified and from destroying parallel operation of alternators.

Each engine is also fitted with one McIntosh & Seymour electrically operated speed changing mechanism which is situated in the governor, and is operated by a small induction motor, and is controlled from the switch board gallery. This arrangement not only allows the engine while running to be speeded up or down four or five revolutions to bring two or more engines into synchronism, but is also used to divide the load between engines.

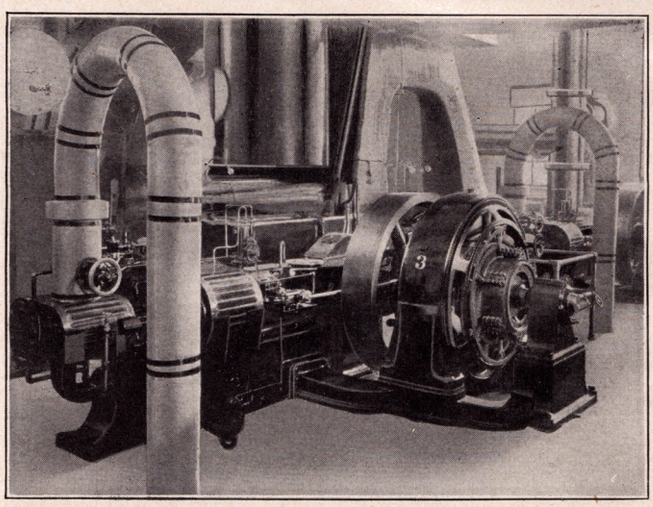
Engines are fitted with metallic packing on all piston rods and on all valve rods. The packings on low pressure cylinders are designed to minimize the leakage of air into the low pressure cylinder which tends to destroy vacuum in the condensers. Engine cylinders are lubricated by suitably designed force feed cylinder lubricators.

EXCITERS:

Situated beside each main engine is one 75 K.W. General Electric Exciter direct connected to one 9x17x12 Harrisburg tandem-compound non-condensing piston valve side crank automatic enclosed self oiling horizontal engine. These engines are designed for the same pressure and superheat as the main engines and operate very satisfactorily under this condition of service.

WHEELER SURFACE CONDENSERS:

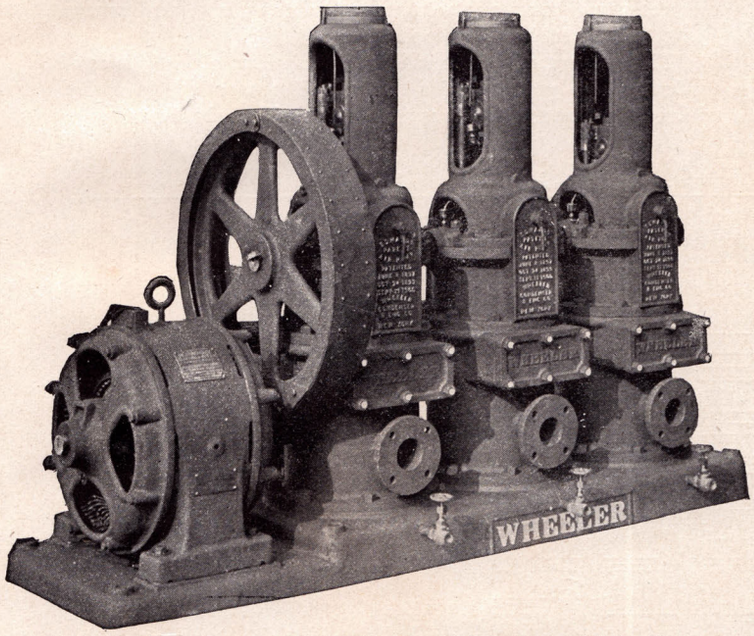
The plant contains six Wheeler "Admiralty" surface condensers, one being for direct connection to each low pressure cylinder of each main engine. Each condenser contains 5200 sq. ft. of cooling surface. Tubes are brass ¾" O. D. No. 18 B. W. G. In addition to the regular cooling surface of each condenser, there is provided in the upper compartment a series of tubes comprising what is termed the "Volz Heater." After being discharged from the air pump the condensed water passes through this Volz Heater under atmospheric pressure and is heated to within a few degrees of the temperature of the exhaust steam surrounding the heater tubes. The make-up water is also brought in at this point, securing the benefit of heat which would otherwise be wasted.



No. 3 Harrisburg Exciter Engine

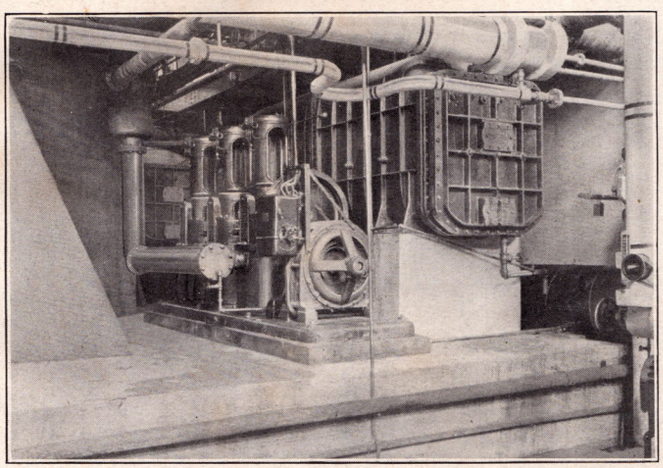
There is furnished in connection with each condenser one Edwards vertical triplex air pump, having three cylinders 16″ in diameter, 10″ stroke, single acting. This air pump is of the suction valveless type, all suction valves being dispensed with. The condensed steam and non-condensible vapors flow continuously by gravity from the condenser to the base of the pump and are removed by a conical bucket or piston,

EDWARDS AIR PUMPS



Edwards Patent Suction Valveless Air Pump, Motor Driven Triplex Type

which works in a base of similar shape. By the action of the bucket, the water is projected without shock at a high velocity through the ports which are cast in the sides of the working barrel. The rising water is followed by a rising bucket, closing the ports and forcing the water and air through the discharge valves of the pump. Each pump is driven by a 25 H.P. Gen-



Edwards Triplex Motor Driven Air Pump and Wheeler Condenser

eral Electric induction motor mounted on an extended base and connected to the pump by a rawhide pinion.

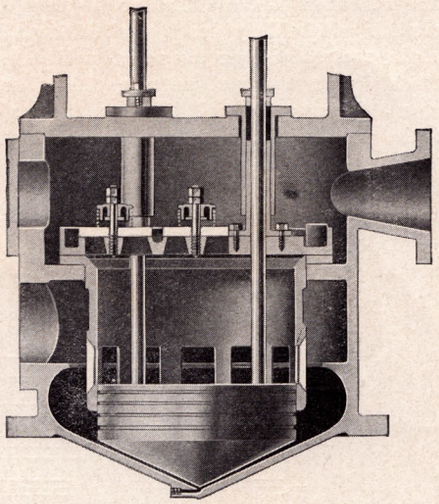
Only one-fifth of the rated power of this motor is required during nominal conditions of load.

There are furnished three engine driven centrifugal circulating pumps, having 20″ diameter of discharge and two 15″ suctions. Centrifugal pumps are of the double suction type, specially designed for high efficiency service. Each pump is provided with an outboard bearing of the

CIRCULATING WATER PUMPS:

ring-oiling type, the pump and bearing of which are mounted on an extension of the entire base.

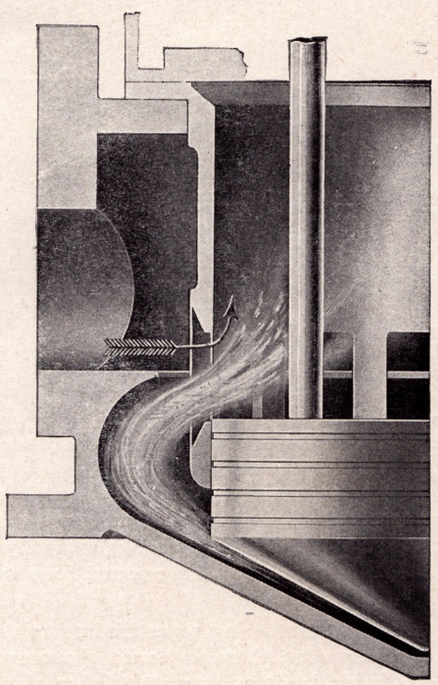
Direct connected to each pump there is a 9x17½x12 Harrisburg tandem compound non-condensing piston valve engine. The limiting speed of this engine is controlled by a throttling governor. An adjustable eccentric enables the economical adjustment of the point of cut-off in the engine.



Section of Edwards Suction Valveless Air Pump

There are four Snow duplex horizontal boiler feed pumps, having compound steam ends, outside center packed water ends. Each pump is of ample capacity for one unit, the fourth pump being for reserve. The pumps operate non-condensing, the exhaust steam being led to the feed water heaters.

BOILER FEED PUMPS:



Section of Edwards Suction Valveless Air Pump Showing Principle of Operation

There are three Goubert vertical auxiliary feed water heaters of the multiple flow type. Each heater contains 1,000 sq. ft. of effective tube heating surface. The supply of exhaust steam is such that under practically all conditions of load, all of the exhaust from the auxiliaries is utilized within these heaters.

GOUBERT AUXILIARY FEED WATER HEATERS:

Sump

Auxiliary Oil Tank No. 3.

Auxiliary Oil Tank No. 2

Auxiliary Oil Tank No. 1.

Arrangement of Boiler Room. (Plan)
15000 K.W. Power Plant, Redondo.
Pacific Light and Power Co.
Los Angeles, Cal.

CHAS. C. MOORE & CO. ENGINEERS.

LOS ANGELES SEATTLE — MAIN OFFICE SAN FRANCISCO. — SALT LAKE NEW YORK

DRAWN BY	R N M	SCALE	1/8 in. = 1 FOOT
CHECKED	C.C.M.	DATE	April 15, 1907
APPROVED	C.P.W.	DRAWING No.	2360.

PLAN OF BOILER ROOM

FUEL OIL PLANT:

Fuel oil is stored in large steel tanks having a storage capacity of from 30 to 45 days. The oil is pumped into auxiliary tanks outside of building at one end of the boiler room, each tank having a capacity of 1000 barrels. The top of the auxiliary tanks is on the same level as the boiler room floor line to conform to the Underwriters' requirements. The grade line is about 14 ft. above the floor of tanks, and the surrounding earth is withheld by means of circular retaining walls. These tank pits are roofed over, properly ventilated. All pipes connecting to tanks, have valves located on the boiler room side, there being a 3 ft. concrete wall between the tank compartments and the operator. There are fire partitions between adjacent tanks and fire proof doors connecting. The manhole covers in each tank are padlocked, so that it is impossible for an operator to set fire to any of the tanks as finally designed, although a fire did occur before these precautions were finally adopted.

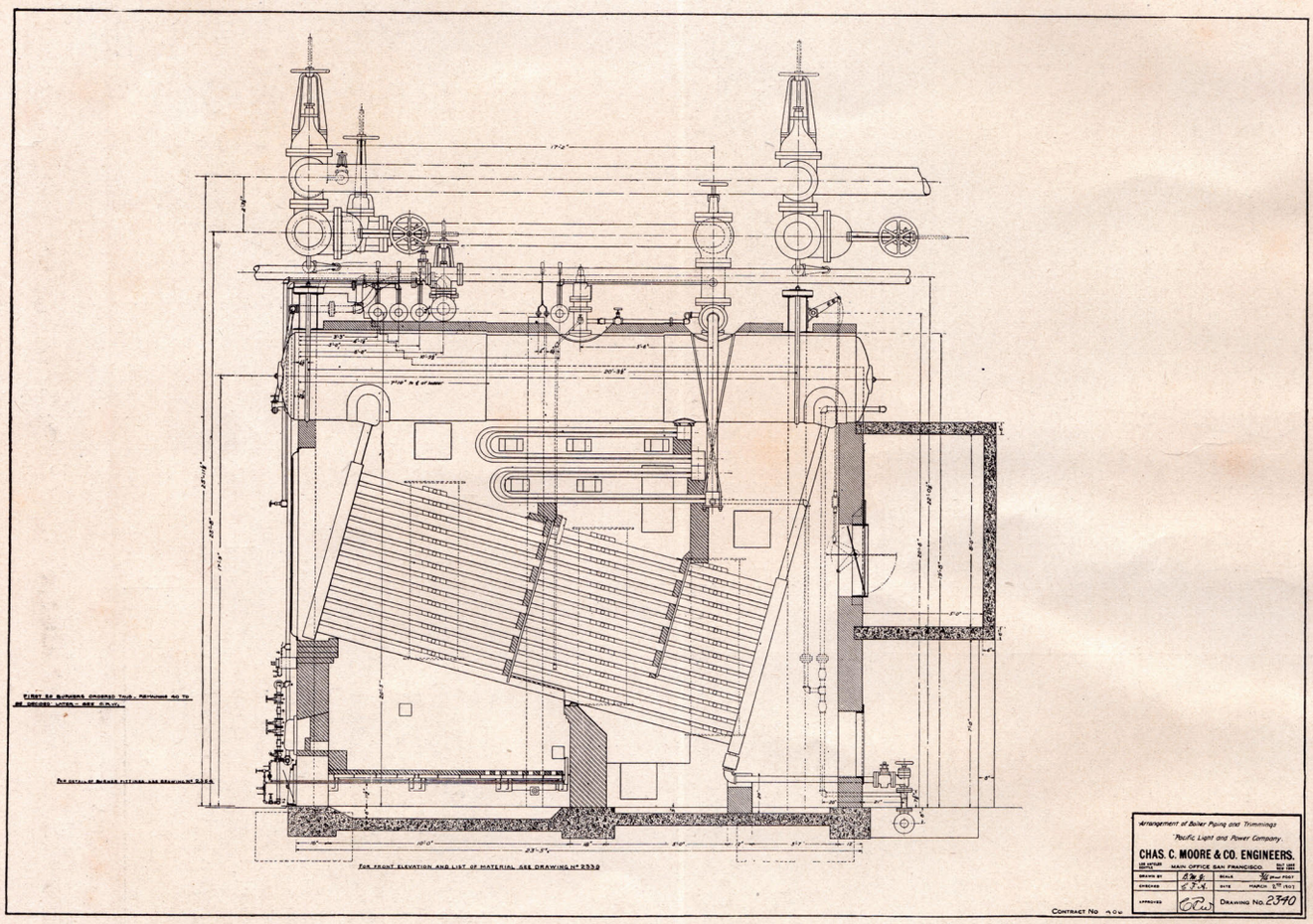
In lieu of steam smothering pipes leading to the interior of the tank compartment, there is placed above each tank, a steam ring of 4" pipe, having an ample number of jets to provide a sheet of steam which would effectually cut off any supply of air from the outside, and promptly smother a fire which might be started by any possible means. This fuel oil installation includes features of design for fire protective purposes which are believed to be the most modern yet adopted.

As originally laid out there was provided a duplicate set of oil feed pumps for each unit, or six oil pumps in all. The plant is so far operated in this way, although it is now being remodelled to have one set of pumps to supply the entire station, requiring but one pump operator instead of three on each shift.

An automatic system of regulation is employed, invented by J. R. Atchison and C. R. Weymouth, the patents for which are controlled by Chas. C. Moore & Co. Engineers.

The oil is pumped under pressures varying from 10 to 50 lbs., depending on load conditions, there being a uniform oil pressure throughout all portions of the plant, all burners being wide open or nearly so.

The amount of oil burned, with variations of load, is controlled by the pressure of oil at the oil pumps, the intensity of fire increasing and decreasing in all boilers simultaneously.


Arrangement of Boiler Piping and Trimmings
Pacific Light and Power Company.
CHAS. C. MOORE & CO. ENGINEERS.
MAIN OFFICE SAN FRANCISCO
Drawing No. 2340

Sectional Elevation Through Boiler, Showing Oil Furnace, Superheater, Overhead Piping, and Concrete Flue

The oil pressure is automatically controlled by a steam pressure regulator, the variations in oil pressure and intensity of fire being such as to maintain a uniform steam pressure on the plant.

Steam to oil burners, for atomizing purposes, is supplied by a separate low pressure main, the pressure in this main being automatically controlled by variations of oil pressure in the oil main. A ratio regulator is used, automatic in its action, operating to maintain such steam pressure in the low pressure steam main as is necessary to atomize the particular amount of oil burned, corresponding to any momentary oil pressure. In this particular plant, it is found that the proper amount of steam for atomizing purposes is furnished under a steam pressure equal to three times the oil pressure plus 30. This relationship will vary with the type of burner used, relative areas of burner orifices for steam and oil.

The air supply for combustion is controlled by a damper controller, also automatic in its action, which increases the damper opening with an increase in oil pressure and vice versa. The movement of the controlling lever is due to the oil pressure acting on a diaphragm. This movement is opposed by the action of a spring, such that the amount of movement on the main lever is proportional to the oil pressure. This movement is multiplied through a hydraulic cylinder connecting to a rock shaft running over all of the boilers in one panel. Each boiler damper is connected to this shaft. The connecting levers are set at such angularity, with respect to the connecting rods operating the dampers, as to give the proper air supply for the various ranges of load, the final adjustment being from actual trial at the plant.

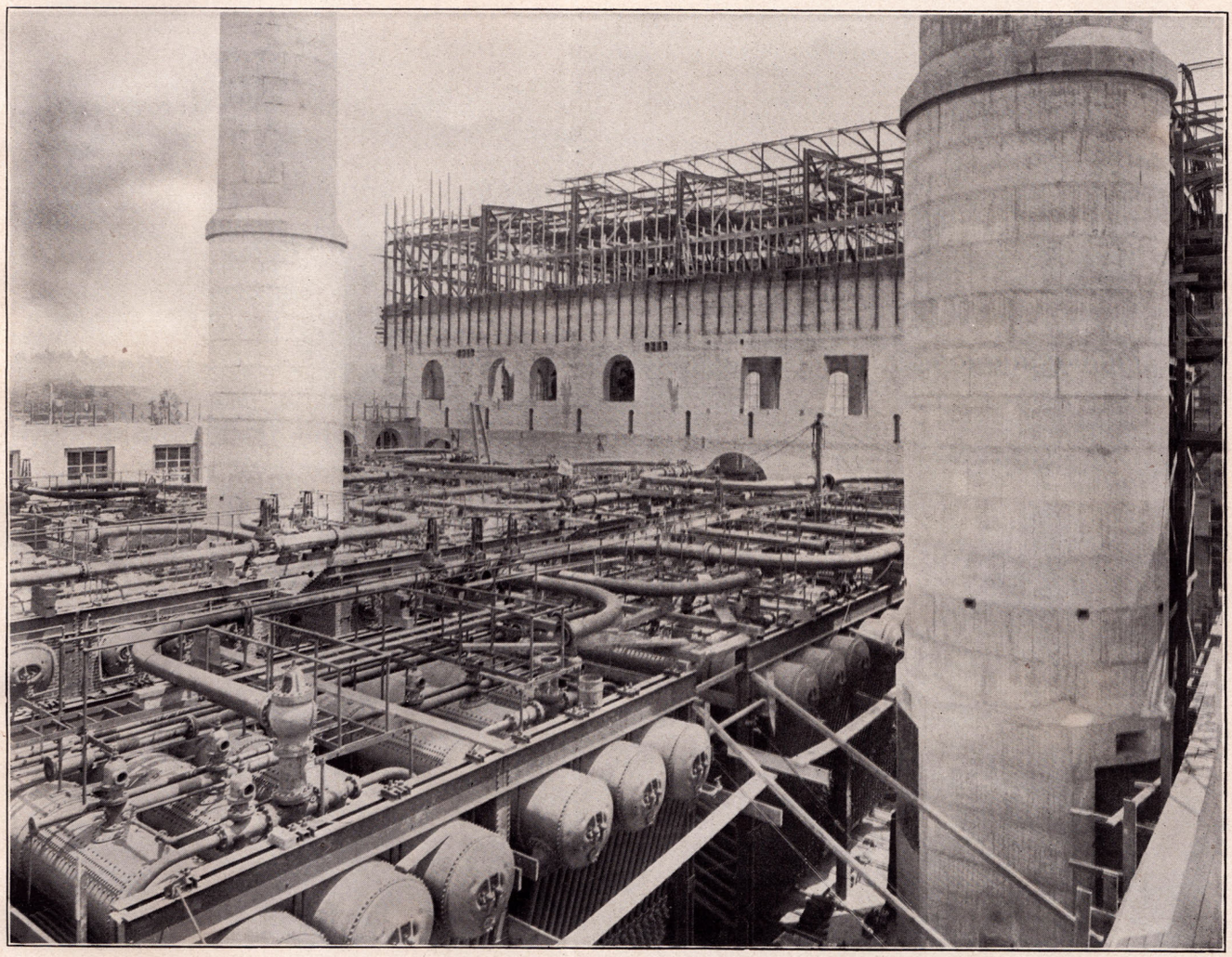
In actual operation and test, it is found that this automatic system of control is safe, reliable and meets with the approval and hearty endorsement of the firemen. Owing to the fact that the firemen's work is very much simplified by the use of these regulators, they are as much desired by the firemen of the plant as by the management; and were it not for this accord, such automatic contrivance could not be successfully installed and operated by the class of labor met with in the ordinary fire room.

A detailed description of this novel system of automatic regulation for oil firing will be made the subject of a special article to be published at a later date.

The air pump discharge is pumped through six marine type feed water filters, 48″ in diameter, 5 ft. in height. Each filter has five compartments of filtering material, suitable for the elimination of the greater portion of entrained cylinder oil.

FEED WATER FILTERS:

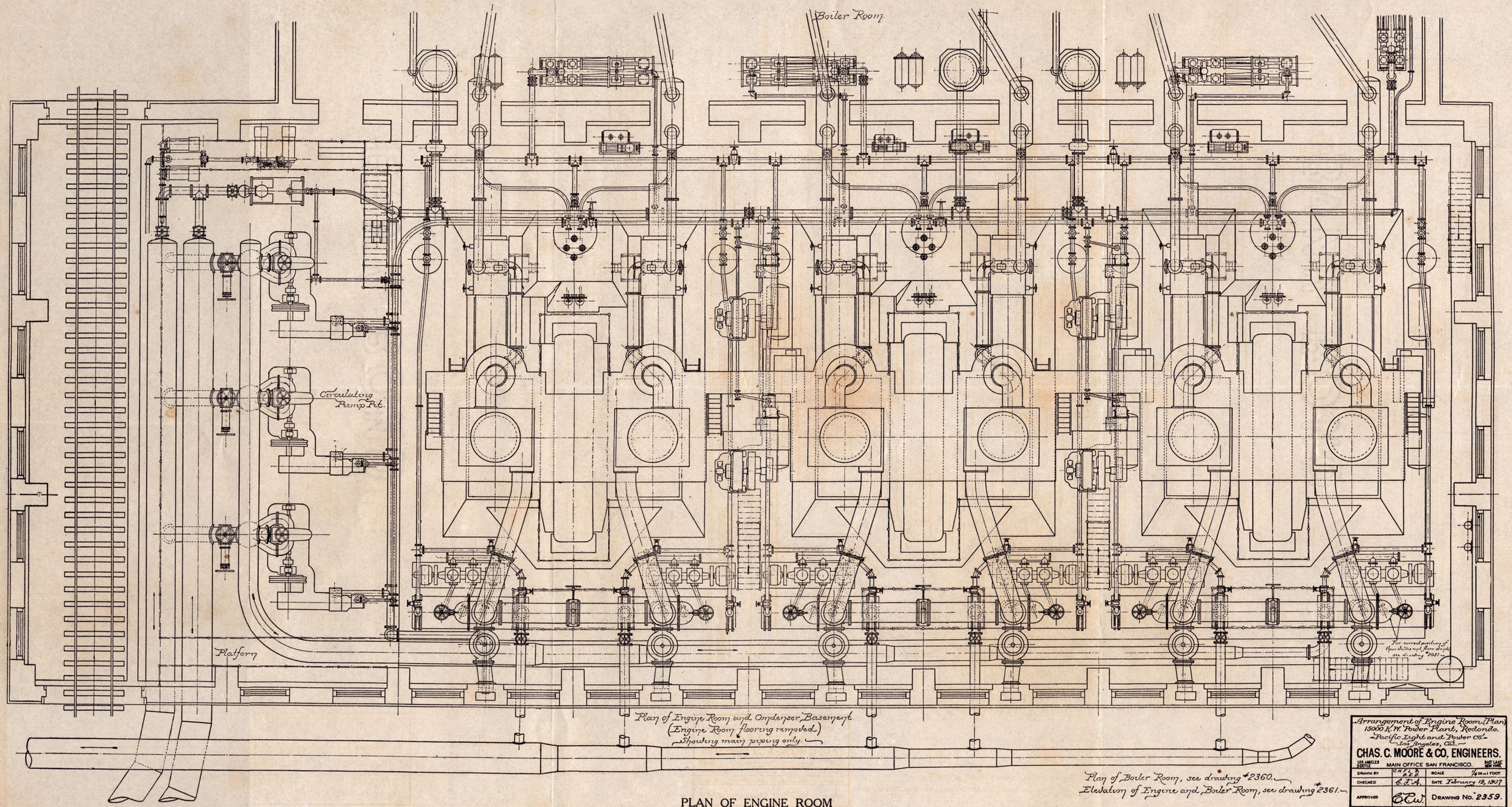
In the operation of this filter the discharge is into the top of the filter. The water passes down through the filtering material and out at the bottom to a stand pipe, maintaining a complete submergement of the filtering material. Owing to the slow velocity of the water through the filter, there is a tendency for any oil, not absorbed by the filtering material, to rise to the surface rather than to be carried on and into the boilers by the downward flow of water.



Boiler Room—Showing Main Steam Piping

The general arrangement of main steam piping is shown on the accompanying drawings. All of the piping of the plant except for some of the minor auxiliaries, is arranged on the panel system, dividing the plant into three independent units. In the lay-out of this station it was desired to reduce the diameter of steam mains. On each high pressure cylinder of each engine, the throttle valve is for 14″ pipe. Owing to the necessity for long radius bends, and the desire for flexibility, it was determined not to employ any steam pipes over 14″ in diameter. It was finally decided to connect three boilers in each battery to each side of each unit; thus providing a greater flexibility of service without increasing the cost

PIPING SYSTEM:


Boiler Room
Circulating Pump Pit
Platform
For curved coupling of Pipe Bells and Flare Bends see drawing #2051
Plan of Engine Room and Condenser Basement.
(Engine Room flooring removed.)
Showing main piping only.
Plan of Boiler Room, see drawing #2360.
Elevation of Engine and Boiler Room, see drawing #2361.

PLAN OF ENGINE ROOM

Arrangement of Engine Room Plan
15000 K.W. Power Plant, Redondo.
Pacific Light and Power Co.
Los Angeles, Cal.

CHAS. C. MOORE & CO. ENGINEERS.

LOS ANGELES & SEATTLE — MAIN OFFICE SAN FRANCISCO. — SALT LAKE & NEW YORK

DRAWN BY	C.N.F. E.E.D.	SCALE	1/8 in = 1 FOOT
CHECKED	E.J.A.	DATE	February 19, 1907
APPROVED	C.C.M.	DRAWING No.	2359.

of the piping system; hence, in so far as the main steam piping is concerned, the plant can be considered in effect six independent units. The main steam piping was anchored to the building walls and building columns located with this idea in view. It was found, however, that the columns were not sufficiently rigid for anchorage purposes, and it became necessary to install a cross system of bracing from wall to wall. Drainage is afforded by locating a large receiver drum in each line of piping, as shown in the drawing.

In all high pressure steam piping 5" diameter and over, up-set lapped joints were used with rolled steel flanges, being an improved type of Van Stone joint. Bolting and thickness of flanges was very conservatively designed in order to prevent leakage, and in this respect the contractors have succeeded in making an absolutely bottle tight system of piping.

As but a moderate degree of superheat is required, the valves and fittings are of semi-steel, have bronze mountings, and Detroit-Edison necks to prevent leakage of steam around valve spindles, etc. Chapman Valve Mfg. Co.'s valves were furnished throughout the plant.

Special consideration was given to the design of exhaust piping to provide the most direct course from the engine to the condenser. As will be noted in the drawing, there is but one bend between the engine exhaust outlet and the condenser inlet and this is of exceptionally long radius. Exhaust pipes have been made of large diameter to lower the velocity of exhaust steam and under actual test the loss in vacuum between the condenser shell and exhaust nozzle was at all times less than ½" mercury column.

The plant is complete with modern arrangements for handling and storing cylinder oil, filtering oil, etc. Compressed air is used to deliver the filtered oil to the various parts of the plant.

All high pressure steam piping is covered with non-conducting covering 3" in thickness, there being valve body and flange covers throughout. The effect of this heat insulation has been to greatly economize the pipe radiation.

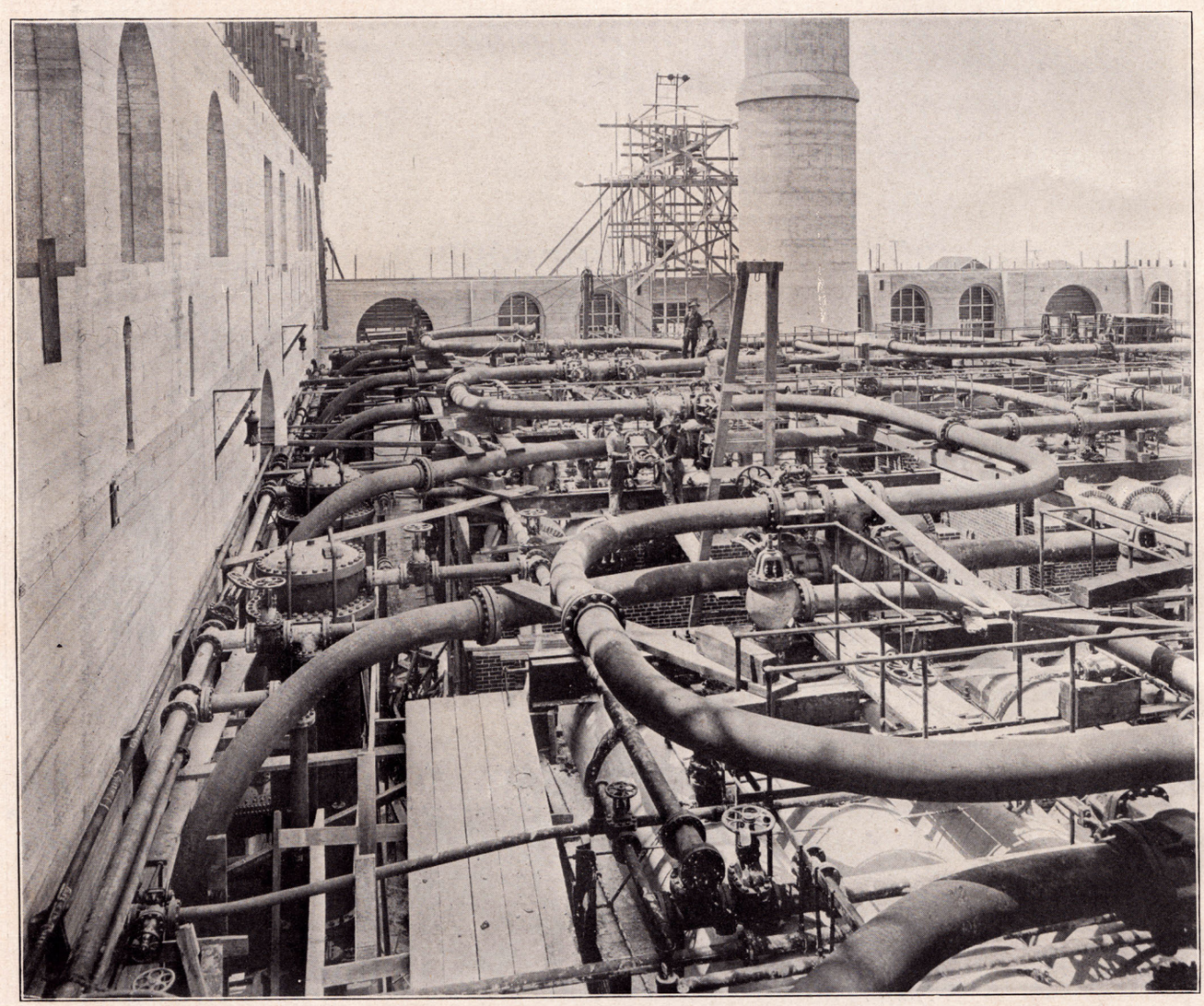
NON-CONDUCTING COVERING:

In pump pit has been installed an Underwriters' Fire Pump, fitted for salt water. This pump also serves as a pressure pump furnishing pressure water for the Lagonda power driven cleaner for boiler cleaning purposes.

FIRE PUMP:

For the purpose of providing circulating water for cooling main engine bearings and guides, which are hollow, designed for such cooling, a set of circulating pumps and inter-cooler have been furnished. Fresh water is circulated through the engine parts and is cooled by means of a small surface condenser; the fresh water for cooling flows

COOLING SYSTEM FOR MAIN ENGINE BEARINGS:

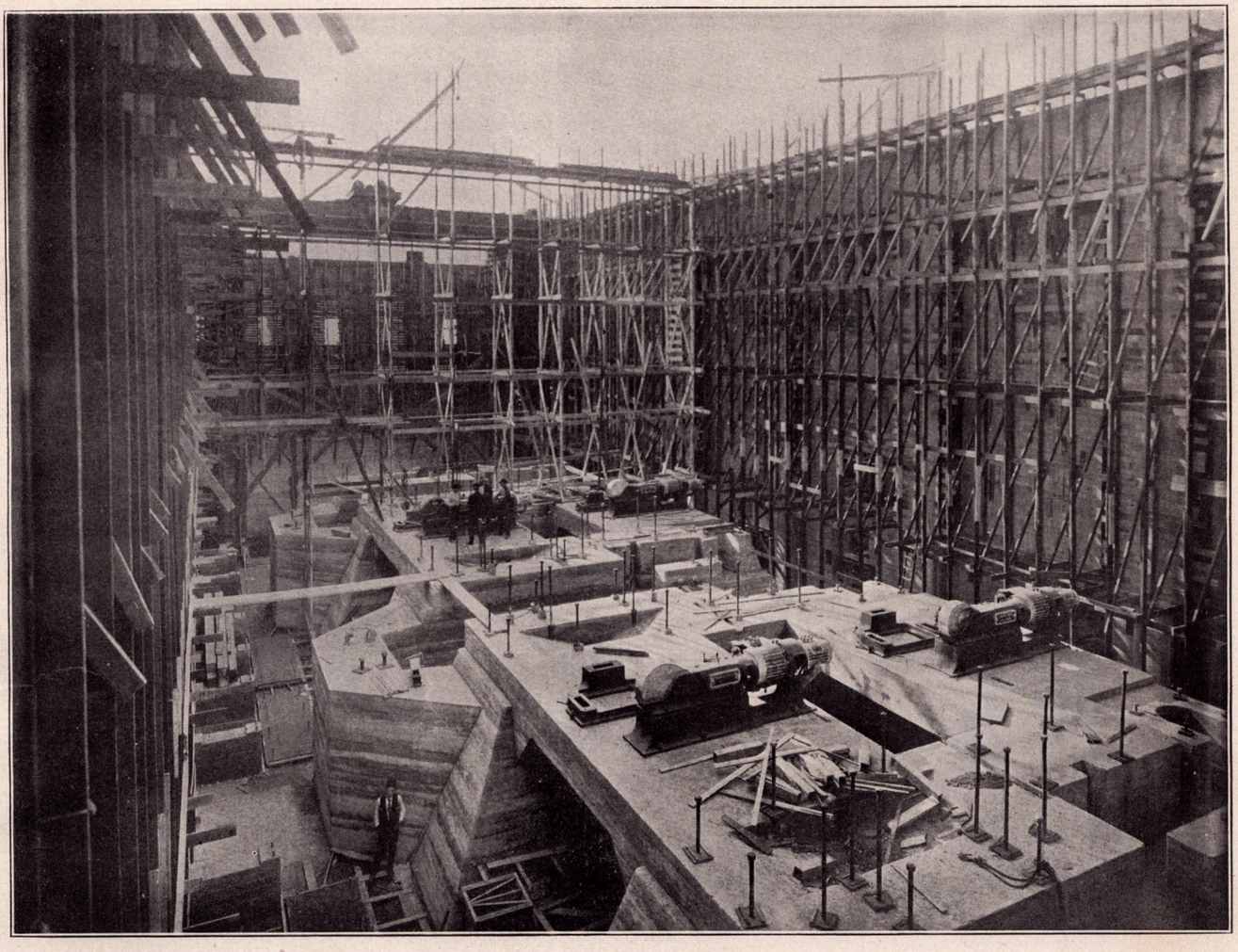


View of Boiler Room Piping During Erection

within the tubes and salt water is circulated around the tubes, being taken from condensing water suction mains.

CHIMNEYS: There are two reinforced concrete chimneys each 13 ft. diameter, 125 ft. in height. Each chimney is of capacity for two units, the plant being so arranged that a fourth unit may be added to the station and connected to the second chimney.

The chimney gases pass from boiler to chimney through specially designed reinforced concrete flues; these have proven eminently satisfactory for the work, although slight heat cracks appear in the concrete in various places.



View of Engine Foundations

ENGINE ROOM CRANE: For convenience in erecting and handling machinery there was installed a 62½ ton Nile-Bemont-Pond electrically operated engine room crane. Railroad tracks allow cars to enter building at one end, heavy machinery being unloaded by crane direct to engine foundations.

FOUNDATIONS: The plant is installed on the beach within a few hundred feet of the surf line. The sub-soil consists largely of drift or pit sand.

In order to prevent vibration due to the main engines, the design of sub-foundation was carefully studied. It was finally determined that in lieu of piling, there would be constructed a sub-foundation 6 ft. in depth the entire length and width of the engine room, except a 2 ft. space all around to prevent interference with building foundations.

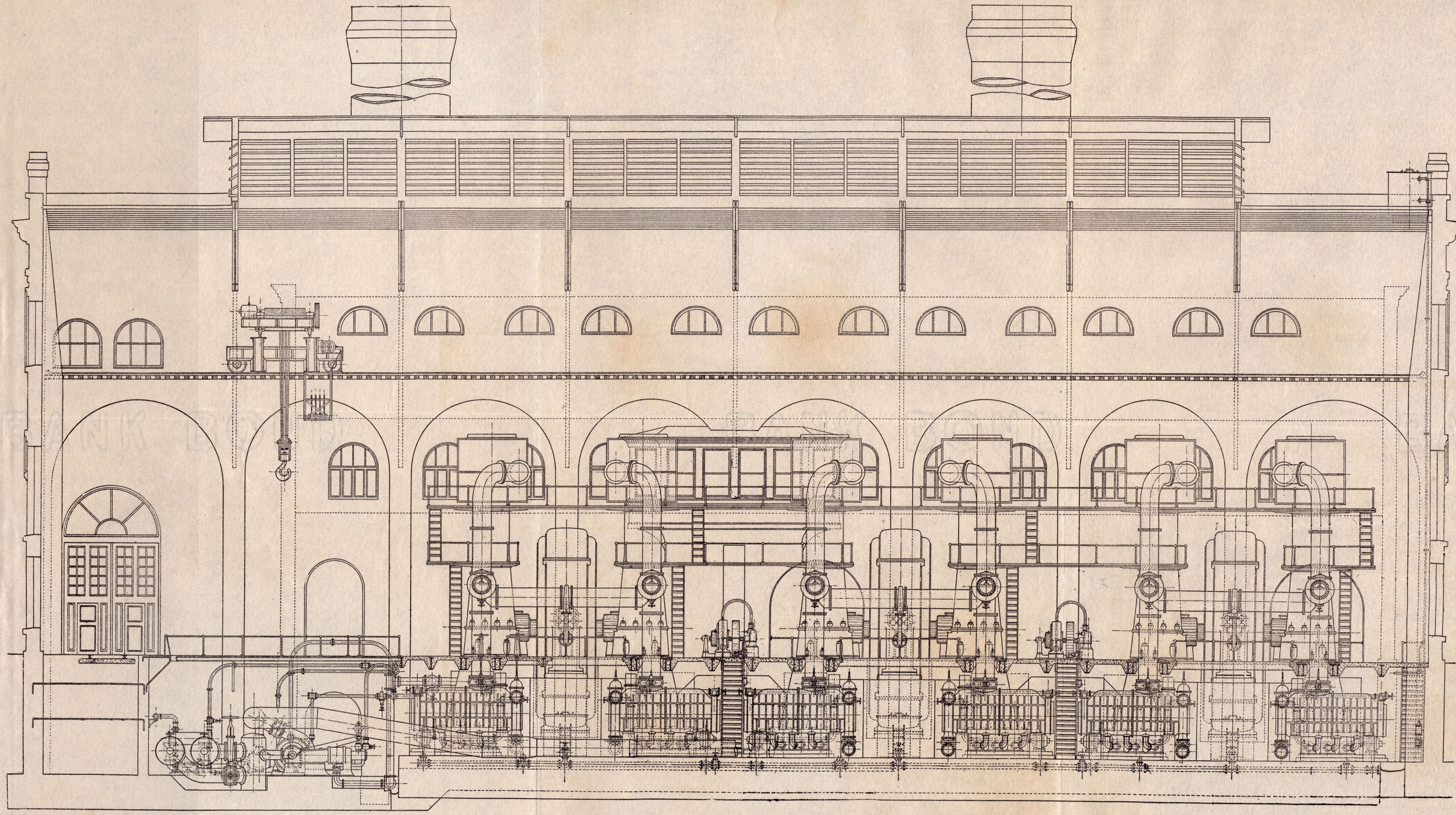
This slab is reinforced top and bottom at the critical points. The main engine foundations were built directly on top of this slab rising 14 feet to the engine room floor line. Foundations for exciter engines were made by arching over the space between adjacent units suitably strengthened with reinforcement, thus affording ample space underneath for rheostats, filters, etc. Photographs are here reproduced showing the main engine foundations complete.

Real Estate restrictions made it necessary to locate the plant at some distance from the ocean. The shallow beach line made it further necessary to carry a wharf built some distance into the ocean in order to obtain the necessary depth for suction at low tide. The centrifugal circulating pumps are located in the pump pit, the center of pumps being about 12 feet above mean low tide. The combined suction and discharge piping comprises a length of 1700 feet.

CIRCULATING WATER SYSTEM:

The circulating system consists of two suction pipes 50″ in diameter made of sheet steel. There is but one discharge line 50″ in diameter. The suction intakes are open ended, the strainers and the sand settling tank being located at the beach end of wharf.

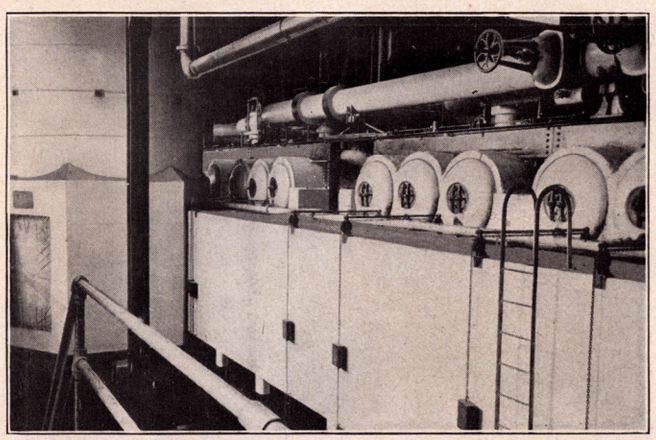
As ocean surf is impregnated with air which must be removed from the suction line under vacuum, and further, in order to prime the suction line before starting, after periods of cleaning, a large duplex motor driven vacuum pump was installed. This vacuum pump removes the air by means of a stand pipe rising 40 ft. above tide, located at the high point of the line.



LONGITUDINAL ELEVATION OF ENGINE ROOM

GENERATORS:

The three main generators manufactured by the General Electric Company, are of particular interest on account of the extremely high voltage, 18,000 volts, for which they are wound. These generators are rated ATB—60 poles, 5000 Kw., 100 RPM—18,000 volts, 50 cycles, three phase, and are of the engine driven, fly-wheel type. The following data may be of interest:—



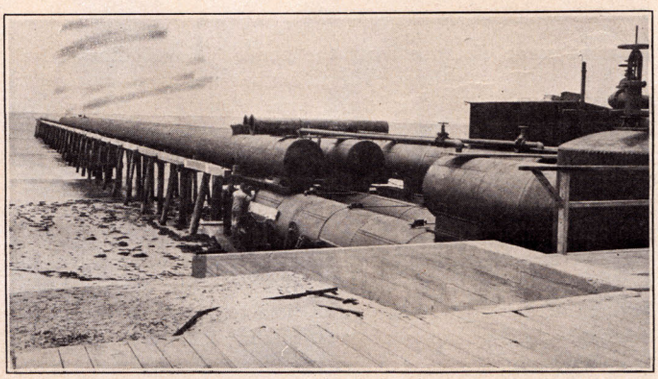
Chimney and Breeching both of Reinforced Concrete

Floor space required ...	.....31 ft. by 6 ft. 9 in.
Diameter of Stator	.....28 ft. 6 in.
Diameter of Rotor	.....25 ft.
Radius of Gyration	.....8.8 ft.
Weight of Stator	.....186,000 lbs.
Weight of Rotor.....	.....162,000 lbs.
Weight of accessories ..	..... 12,000 lbs.
Total weights	.....360,000 lbs.

The commercial efficiencies at unity power factor are as follows:—

1.25 Load	.....96.5%
Full "	.....96.2%
0.75 "	.....95.2%
0.50 "	.....93.5%
0.25 "	.....88.0%

The armature coils of these generators have stood a high potential test of 40,000 volts for one minute.



Circulating Water Suction and Discharge Line to Ocean

On account of the severity of the specifications in regard to the operation of these generators in multiple with existing apparatus on the transmission system of the Pacific Light & Power Co. the revolving fields are provided with a squirrel cage winding to prevent hunting.

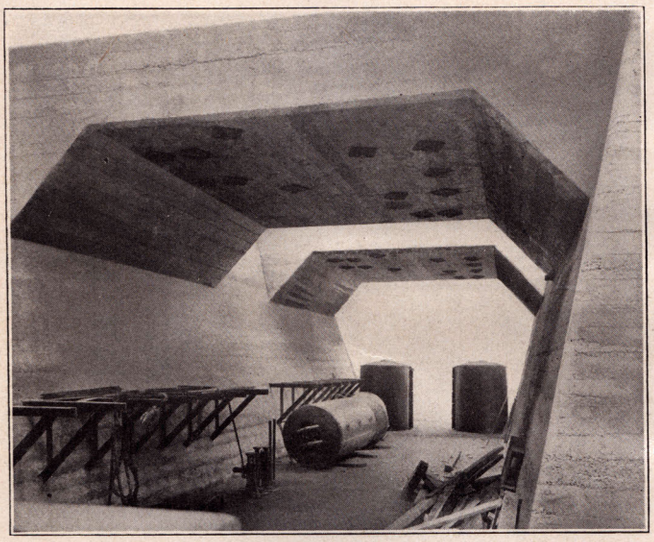
The generator field rheostats are motor operated, with remote control from the switchboard.

The starting, stopping and loading of the various units, is controlled entirely from the switchboard gallery, located above the boiler room and along side the main engine room wall.

SWITCH BOARD EQUIPMENT:

The following description of switch-board gallery was furnished by E. R. Davis, Electrical Engineer for the Pacific Light & Power Company :—

"The generator wiring between the generators and switchboard room consists of three 4/0 bare copper wires, each in a separate duct, on large porcelain insulators. In connection with this we installed one spare duct and spare cable for use in case any of the three main lines break down or become defective. Each generator is connected through 2-way porcelain mounted selector switches to either of two sets of high tension bus bars; these bus bars being located in two separate concrete galleries. The feeders, two each to the L. A. Ry. Co. and the P. E. Ry. Co., are also connected through 2-way porcelain mounted selector switches to either of two sets of high tension bus bars, the purpose being that we may be able to kill and repair oil switches, insulators, etc., in either bus bar gallery without interfering with the operation of the gen-



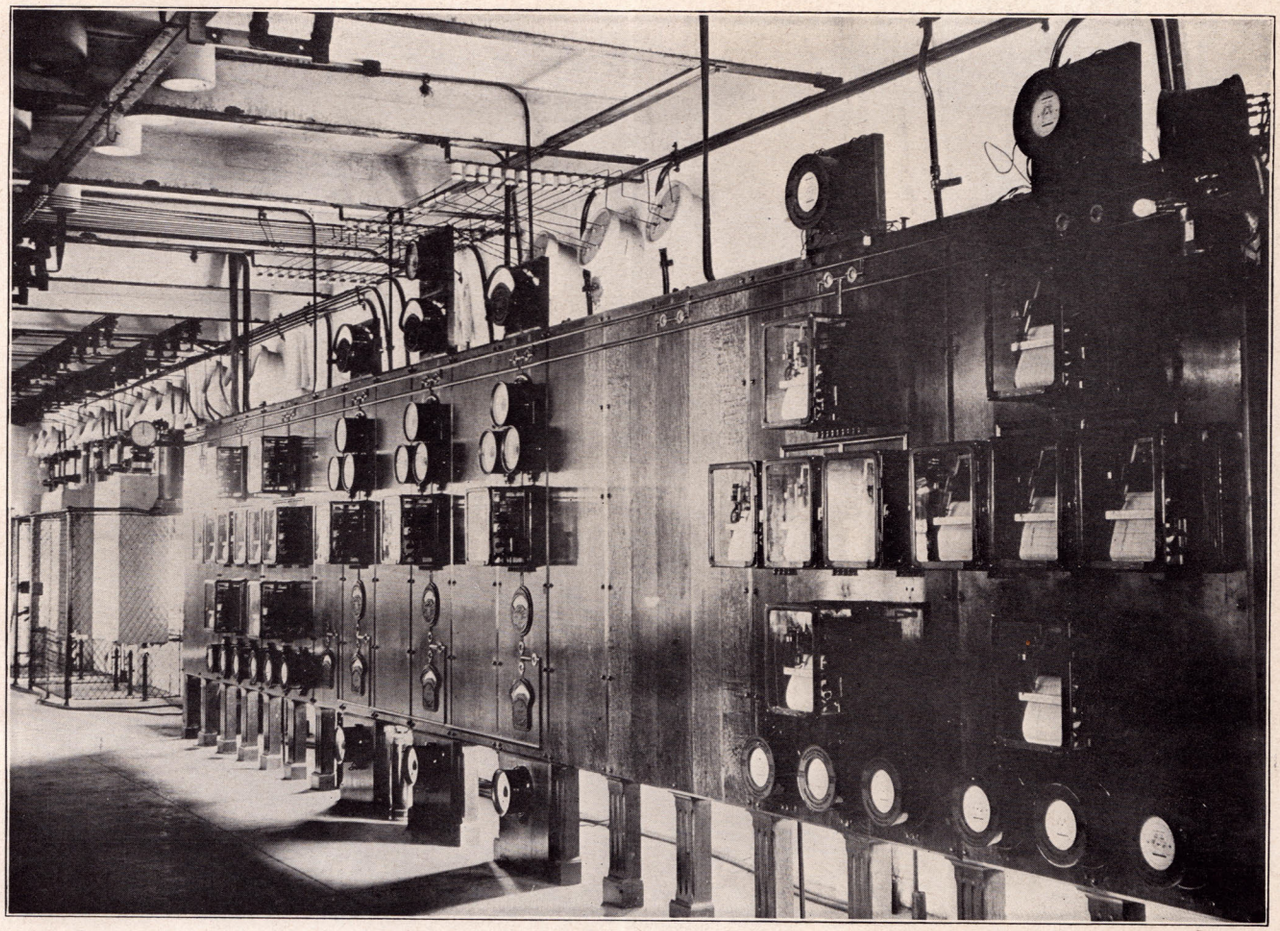
Concrete Arches Between Main Engine Foundations Supporting Exciter Engines

erators or the distributing feeders. The oil switches are the single cell, single throw, 4 break, 400 ampere switch, mechanically connected together in gangs of three poles. These switches are operated by manual remote control, and the entire equipment was built in the shops of the Pacific Light & Power Co. The operating stand and the instrument board are made from well seasoned oak, the object of using wooden construction in this particular being partly due to the saving in expense in building wooden structure instead of marble, but principally due to the fact that on account of the rapid progress of electrical science our switchboards rapidly become obsolete, and if made of marble they would be extremely expensive and hard to replace. With reference to the danger from fire hazard in connection with wooden structure, beg to state that all the high tension alternating current wiring is communicated to the switch-board instruments through the low tension wiring of current and potential transformers, said low tension wiring being permanently grounded; approximate voltage on same being 120 volts. The alternating current instruments used in connection with the feeders and generators on this switch-board are the curve tracing Westinghouse

graphic recording type. The exciters and field circuits are equipped with Weston D. C. instruments.

"The lightning arresters in connection with this station were furnished by the General Electric Co.—two sets in connection with the contract from your people, and the second two sets purchased by ourselves at a later date.

"The exciters, four in number, are wired up to the marble switch-boards located on the main engine room floor, the switches being operated by remote control, using air for this purpose. The wiring is so designed that under ordinary conditions each main unit has its independent exciter, and should anything happen to the particular exciter, the fourth or spare exciter, might be connected to any of the main units.



View of Switchboard

"Field rheostats in connection with main generators are motor driven for remote control.

"The auxiliary induction motors in connection with the Edwards Air Pumps, small circulating pumps, condenser and feed water motors are operated from a bank of step-down auxiliary transformers connected to the main generator leads.

"Will state that the operating room and galleries consist entirely of reinforced concrete construction and are in every detail entirely fire proof."

FEED WATER PURIFIER: The make up water for the plant is supplied by wells on the property of the Company. This water contains certain carbonates and sulphates and is purified before being supplied to the plant by means of an automatic purifier.

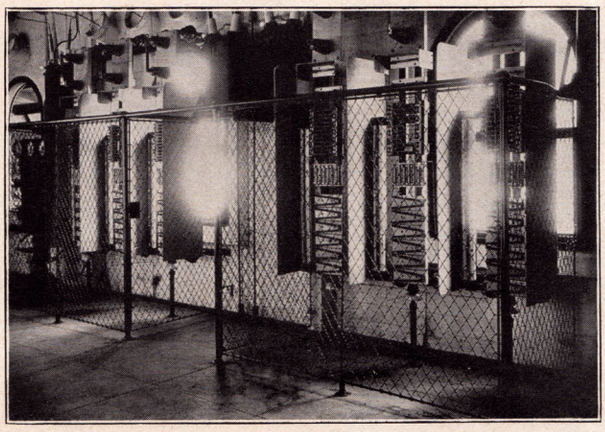
BUILDING: Building, foundations, wharf, and circulating water pipe line, were designed and installed under the direction of Edwards S. Cobb, Chief Engineer for the Pacific Light & Power Co. The building is entirely of reinforced concrete, erected by Carl Leonardt, a prominent Southern California contractor. In design of the power plant building, the elements of economy and simplicity were given first consideration, although a decidedly pleasing architectural appearance has been maintained throughout. For its purpose of use, the power plant building is unquestionably the most appropriate of any in the West.

The installation of machinery and the erection of building proceeded at the same time. The engine crane was erected as the side walls were carried up. It became necessary in hastening completion to use the crane before the roof and roof bracing was in place. With concrete less than 30 days old the full weight of 135,000 lbs. live load was carried by the crane the length of the building, without injury to the concrete, a remarkable performance.

OPERATION OF PLANT: Various practical difficulties were met with in starting the plant naturally to be expected in any installation of large size. The entire crew were inexperienced in the handling of machinery of anything of more than one-quarter the size of this station. The difficult task of breaking in the crew, and the operation of the plant was entirely

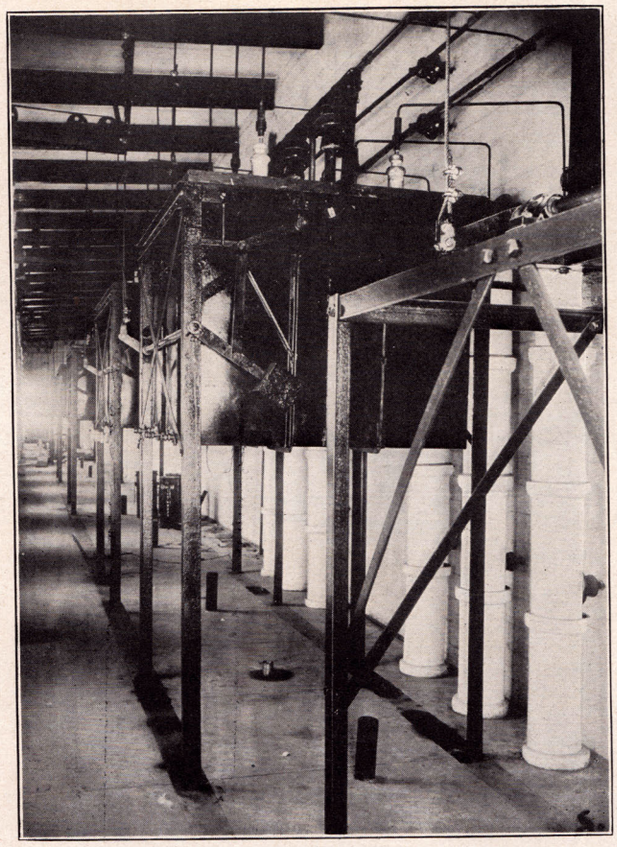
under the direction of Mr. J. R. Atchison, Superintendent of Construction for the contractors, Chas. C. Moore & Co. Engineers, under whose charge the installation work also proceeded.

While the load was carried from the start without serious interruption, it was not until after some time that the operators were thoroughly systemized and familiarized with their respective duties.



Lightning Arresters

While it is the usual practice under Pacific Coast conditions to attempt to filter cylinder oil out of air pump discharge it is contrary to the experience of Eastern stations and represents probably one of the most radical departures from Eastern practice in the design and operation of this plant.



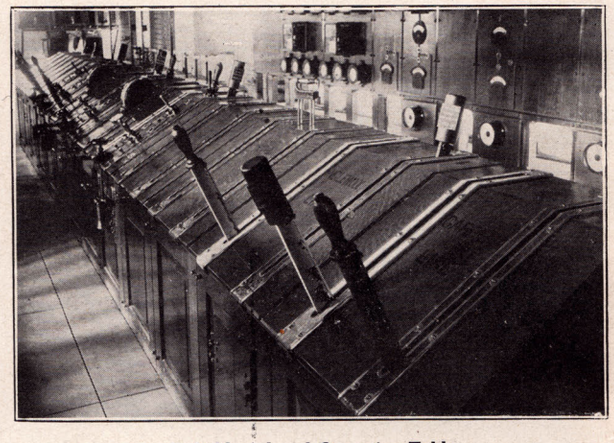
High Tension Switch Gallery

One of the difficulties yet to be solved by the Pacific Light & Power Company, is the elimination of sea weed, and more particularly the fine sea moss from the circulating water which fouls the condensers and gives rise to a frequent loss of vacuum, compelling operation non-condensing. It happens that in the warm climate throughout the entire southern country, there is a large marine growth, consisting not only of kelp but also the finer grades of sea moss; it is impracticable to handle this effectively with any type or make of enclosed strainer. It is probable that some type of open canal screens will be used to remove this most objectionable difficulty.

Some very interesting results have been accomplished at this station in the handling of condensing apparatus during difficulties with sea weed.

As stated above, there are supplied two condensers for each unit. The entire exhaust steam from one unit has been handled by one condenser, the other condenser being temporarily out of service, due to the accumulation of sea weed; the loss of vacuum due to this overloading of one condenser varies from 1½ to 2".

The operation of the Volz heater acting as a primary heater raising the temperature of the air pump discharge is quite effective and results in material fuel saving.



Switchboard and Operating Table

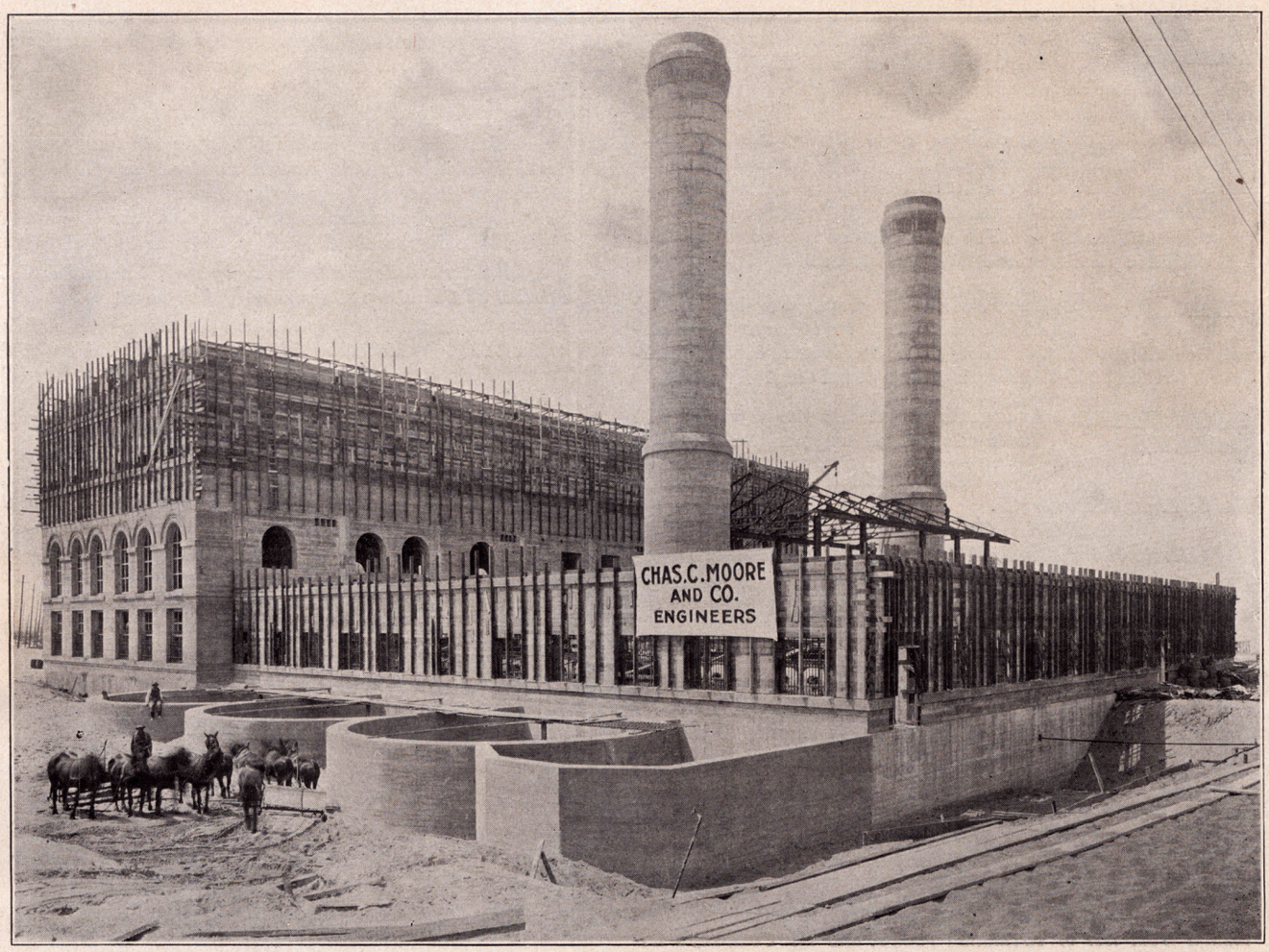
The circulating water system was designed to operate on the syphon system, requiring but a nominal head of from 15 to 20 ft. on pumps. This head at times of accumulation of sea weed would rise to 35 ft. and more. Even with the quantity of auxiliary exhaust steam due to this head, the amount is below the capacity of the feed water heater, so that no exhaust steam is wasted under any normal condition of running.

GUARANTEE:

The contract covering this station embodied an economy guarantee providing for a 90 days test of one unit on a commercial railway load, under any load curve within the limits of the rated capacity of the generator, the total output being not less than 60,000 K. W. hours, nor more than 78,000 K. W. hours per 19½ hours running, there being 4½ hours stand-by each day.

On this load the Company guaranteed an economy of 170 K.W. hours per barrel of oil; each barrel weighing 334 lbs., each pound containing 18,500 B.T.U. The contract provision for a 90 days test was subsequently modified to cover a period of 15 days in view of the fact that the test was not under way until after six months operation of the plant, when running conditions had presumably become normal.

To determine the economy of the plant the contracting parties each appointed a representative, the two jointly selecting a neutral party. The representative for the Pacific Light & Power Company was Edward S. Cobb, Chief Engineer. The representative for Chas. C. Moore & Co. Engineers, was C. R. Weymouth. The neutral member of the Testing Committee was Prof. C. L. Cory, Dean of the College of Electrical Engineering, University of California. Mr. Cobb was assisted by Mr. Edward R. Davis, Electrical Engineer for the Pacific Light & Power Company, and Mr. Weymouth was assisted by Mr. G. C. Noble, Prof. of Electrical Engineering of the University of California, Mr. J. N. LeConte, Prof. of Mechanical Engineering, University of California, and Mr. H. W. Beecher.



Building in Course of Erection. Oil Storage Tanks in Foreground.

Also there were present as contractors' representatives, Dr. D. S. Jacobus, Advisory Engineer for the Babcock & Wilcox Co., Mr. Harte Cook, Testing Engineer for McIntosh, Seymour & Co., and Mr. J. A. Lighthipe, Engineer for the General Electric Co.

The test was one of the most elaborate ever undertaken in connection with a steam power plant. The expense amounted to many thousands of dollars, there being engaged in the work including the three shifts, for the three parties of interest a total of about eighty men.

The Committee's report gave the result of the 15 days test as 252.842 K.W. hours per barrel of oil. There is in this result a slight correction in favor of the contractors due to an excessive sulphur and moisture content of the oil. This record eclipses all published statements of economy of large power plants, operating under commercial conditions. For purposes of comparison with Eastern results, the above economy is equivalent to slightly less than 25,000 B.T.U. in the fuel per K.W. hour net output of plant.

It should be stated that this test was made on a complete unit with the exception of the circulating water pump. The actual head under which the plant now works due to sea weed difficulties, varies from 30 to 35 ft. The contract provided that the Purchaser supply a syphon system of circulating water piping, so that the total head of friction and flow would not exceed five feet. An allowance was made for the omission of the circulating pump by deducting from the total bonus earned a suitable sum. It can be safely stated that the reduction in economy due to the energy to drive circulating pump would have been a small fraction of 1%, particularly in view of the fact that all of the exhaust steam would have been utilized in the feed water heater.

The bonus earned as a result of the above economy was $363,310.00, which is undoubtedly the largest bonus ever paid on a steam power plant guarantee.

At the time this contract was closed it was necessary that the Purchaser have substantial protection as to the cost of power produced by this station, the plant output being contracted in advance at rates calculated from economy guaranteed, which in itself was in advance of any economy then realized with fuel oil. While none expected such an unprecedented gain over the stated economy, yet from the very nature of its business, sound business policy offered to the

management no alternative than these guarantee stipulations.

Based on the local market price of crude oil, the fuel saving due to this gain in economy will pay the full amount of bonus, in from two to three years' time, thus making this bonus a gilt-edge investment; the saving during the remainder of the life of the plant representing an enormous gain for the Purchaser.

COMPARISONS WITH TURBINE STATIONS: It may be surprising to Eastern Engineers that a power plant of this magnitude should be undertaken with the use of steam engines in lieu of steam turbines. At the time this contract was drawn, a most careful investigation was made by the Pacific Light & Power Company under the direction of its General Manager, A. C. Balch. As a result of most extensive inquiries and investigations, Mr. Balch determined in favor of reciprocating engines. From the standpoint of economy at least, this selection has been amply justified. On the score of space, the center distance between the engines is 43 ft. Had the exciters been located elsewhere this distance could have been reduced to 35 ft. The first cost of this plant has not exceeded five per cent that of a turbine station.

DESIGN The Power Plant proper was designed by C. R. Weymouth, in Charge Engineering Department Chas. C. Moore & Co. Engineers; except switchboard, building and other work outside of building.

REPORT TESTING COMMITTEE As a matter of interest the report of the Testing Committee is appended :—

Los Angeles, Cal., June 4, 1908.

Pacific Light & Power Co.
Los Angeles, Cal.
(*Hereinafter called the Purchaser.*)

Chas. C. Moore & Co. Engineers,
San Francisco, Cal.
(*Hereinafter called the Company.*)

Gentlemen:—

We, the undersigned, duly appointed Board of Arbitration and Testing Committee, have completed the economy test of No. 2 Unit at the Redondo Power Plant in accordance with all of the provisions as set forth in Contract between yourselves, accepted April 12, 1906, *and in accordance with all of the modifications of said Contract, including the following*:

The Company's letter of July 20*th*, 1906, *regarding modification of auxiliaries, and the Purchaser's letter of acceptance of July* 25*th*, 1906;

The Purchaser's letter of Jan. 3*rd*, 1908, *regarding the elimination from test of circulating pumps, and the Company's letter of acceptance of Jan.* 8*th*, 1908;

The Company's letter of April 8*th*, 1908, *regarding reduction of time of test from ninety days to fifteen days, accepted by the Purchaser same date;*

The Company's letter of Apr. 27*th*, 1908, *regarding change in place of calibration of meters, and the Purchaser's letter of acceptance of May* 18*th*, 1908.

The Company's letter of Apr. 14*th*, 1908, *regarding change in number of meters used in test, and the Purchaser's letter of acceptance of Apr.* 17*th*, 1908;

The Purchaser's letter of May 4*th*, 1908, *regarding the omission of final calibration of meters, and the Company's letter of acceptance of May* 5*th*, 1908.

The proceedings and decisions of your Committee have been embodied in the Committee's Minutes of the various meetings, approved copies of all minutes having been furnished to the Company and the Purchaser through their respective Committee members.

The original observations during the test were made by neutral men under the direction of the neutral member of the Committee. Copies of all originals were made by the neutral observers, one set for the Company's record and one set for the Purchaser's record. All original observations have been retained by the neutral member of your Committee.

In the calibration of electrical instruments, the Committee employed Mr. E. F. Scattergood, of Los Angeles, using certain standards furnished by him, certain standards supplied by the Department of Electrical Engineering, University of California, and certain other standards obtained from the Bureau of Standards, Washington, D. C.

The oil determinations were made by Prof. Edmond O'Neill, Department of Chemistry, University of California.

During the test, the energy required for driving the circulating water pump, for delivering oil from the main storage tanks to the weighing tanks, and for delivering feed water from the wells to the plant under a slight pressure, was not supplied by the unit under test, this being in accordance with the provisions of the Contract.

Your Committee have to report that, in accordance with all the provisions regarding the economy test, as set forth in the Contract, and modifications of the Contract as outlined above, and in accordance with all decisions rendered by the Committee in connection with matters to be decided by the Committee, and after making all proper corrections, the average economy was found to be two hundred fifty-two and eight hundred forty-two thousandths (252.842) *kilowatt hours per barrel of oil.*

Respectfully submitted,

(*Sgn.*) *EDW. S. COBB,*
Member for the Purchaser.

(*Sgn.*) *E. R. DAVIS,*
Electrical Advisor to Purchaser's Member.

(*Sgn.*) *C. R. WEYMOUTH,*
Member for the Company.

G. C. NOBLE,
Electrical Advisor to Company's Member.

(*Sgn.*) *C. L. CORY,*
Chairman.

CHAS. C. MOORE & CO. ENGINEERS INC.

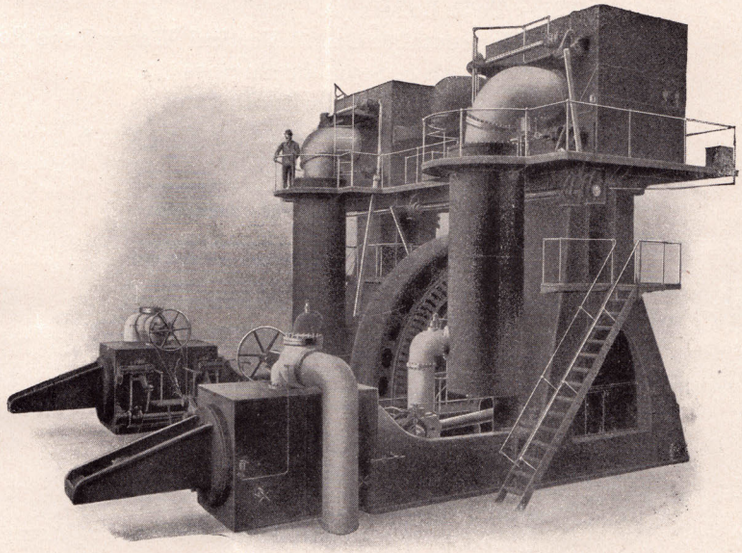
SAN FRANCISCO, CAL.

CONTRACTORS FOR COMPLETE PLANTS

— FOR —

POWER LIGHTING PUMPING MINING

View of Horizontal Vertical 5000 K. W. McIntosh & Seymour Engine



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We are prepared to make plans and estimates, or undertake the installation of any class of Motive Power Work in all its branches, Electric Railway or Lighting Plants, Mining and Milling Machinery, Hydraulic Work, etc.

Branch offices are maintained in the principal sections of the Pacific Coast, the business of which is handled by experienced engineers, assuring customers, in any location, advice and recommendations along the lines of the latest and best practice.

We invite the most thorough investigation of the work we have done, and that we are capable of doing. Continued orders from satisfied customers are to our mind the highest indorsement, and these we are able to show.

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Green's Fuel Economizers
Wheeler Surface Condensers
Barnard Cooling Towers
Edwards Air Pumps
Goubert Feed Water Heaters
Cochrane Heaters and Purifiers
Hoppes Live Steam Purifiers
Leslie Pressure Regulators
Stratton Steam Separators
Snow Steam Pumps
Deane Triplex Power Pumps
Monarch Engines Stop Systems
Reilly Evaporators
Mining and Milling Machinery
Rock Breakers
Wet and Dry Tube Mills
Cement Machinery
Chapman Valves and Hydrants
Weinland Tube Cleaners

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